4 FINAL REPORT 9
FOR
PART NUMBER 4425008-901
"BOTTLE, GAS STORAGE,
GAS BEARING SUPPLY"

Prepared for:

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1.0 INTRODUCTION

This report has been prepared in accordance with the requirements of paragraph D.2.2 of Phase II under Article I of the National Aeronautics and Space Administration Contract Number NAS 8-11751, as issued to Airtek Dynamics Incorporated on July 7, 1964, for the design, fabrication and qualification of nine (9) Gaseous Nitrogen Storage Bottles in accordance with MSFC, NASA Design Procurement Drawing 20M32013.

2.0 SCOPE

The purpose of this report is to summarize the results of the work performed under the contract, including recommendations and conclusions based on the results of that work.

3.0 ABSTRACT

The experience obtained during the manufacture of the tanks, the results of all metallurgical evaluations and the findings from the qualification test phase, have shown that the manufactured vessels met and exceeded the physical and functional requirements of the MSFC, NASA Design Procurement Drawing 20M32013. Since the testing results have shown reasonable positive margins of safety, it follows that certain recommendations, such as a weight reduction program should be instigated.

4.0 CONCLUSIONS

This contract was for the design, fabrication, testing and cleaning of six production units and three qualification test units. The six production tanks were shipped to NASA as follows:

Serial Number	Ship Date
04 (Phase I)	November 30, 1964
05, 06 & 07 (Phase I)	April 1, 1965
08 & 09 (Phase II)	April 1, 1965

The three test units were delivered to the test site on November 30, 1964. The testing was completed on January 30, 1965. The units tested were serial numbers 01, 02 and 03, the fragments of which were shipped to NASA April 6, 1965.

During the fabrication of the production parts and the subsequent acceptance testing, no failures or rejections were experienced.

4.0 CONCLUSIONS (continued)

During qualification testing, three notices of deviations were written. These deviations were:

a) During the vibration test the NASA furnished holding bracket, P/N 20M42067 fractured.

b) Upon completion of the vibration test in Z axis the circular rubber mounting pad in the mounting plate was found to have worn excessively, resulting in loosening of the holding straps.

c) During equalization of random vibration, NASA furnished P/N 20M42048 fractured.

Throughout each of the above occurrences the vessel remained undamaged and successfully passed all remaining tests.

Detail discussions of the noted deviations and the remainder of the qualification test program is set forth in a 156 page test report, number 16564, previously submitted.

At the conclusion of the complete qualification test program the three test specimens were pressurized to rupture. The resulting rupture pressures are as follows:

S/N	Burst Pressure
01	8775 psig
02	8750 psig
03	8750 psig
Average	8758.33 psig

The maximum percentage difference of the burst pressures of the three tanks is 0.28 percent.

Probability of success, statistical calculations based on the above sampling, results in an inherent reliability in excess of 0.999999.

An evaluation of the tensile tests conducted on this program has shown a final average ultimate tensile strength of 174,041 psi.

Since the average room temperature burst pressure is 8,758.33 psig, calculations show that the minimum wall thickness required for this vessel meeting that pressure, and having a uniaxial ultimate tensile strength of 174,041, would be .239 inches. To be comparable with the design minimum wall thickness shown on Airtek Drawing Number 4425008 of .226 inches, which is based on a pressure of 7100 psig at 200°F, the actual burst pressure will reduce to 8,084 psig. The actual minimum wall thickness of the ruptured tank was .231, therefore, the burst pressure should have been 7,701 psig. The 383 psi difference may be attributed to

4.0 CONCLUSIONS (continued)

the biaxial strength factors of 4.5%. These biaxial factors, which are an extension of the Von Mises criterion, are due to the hexagonal, close packed crystallographic structure of Titanium 6Al-4V alloy.

5.0 RECOMMENDATIONS

As a result of the relative high burst pressure that occurred during qualification testing, it seems that in using a somewhat conservative biaxial factor of 4% the wall thickness could be reduced to .217 inches. This would reduce the wall thickness by .009 inches and the weight accordingly by approximately 1.8 pounds.

6.0 MANUFACTURING PROCEDURE

Following is a brief delineation of the manufacturing process used in the fabrication of the subject parts.

6.1 FORGING

Forgings are made by the closed die method in accordance with the requirements of an Airtek Forging Drawing. All heating operations, during forging, are performed in a radiant tube or electric resistant heated furnace, with a clean hearth, using an air atmosphere. Airtek Engineering approval was required on all forging microstructure prior to any machining. Forgings were procured to Airtek Specification AD 7-2.

6.1.1 Each forging is ultrasonically inspected prior to welding to AD 4-5

6.2 HEAT TREATING

Subsequent to a rough machining operation, Airtek solution heat treated and partial aged each forging per AD 1-6. After welding, with argon gas weld sealed inside, the parts were subjected to a final aging operation per AD 1-6, then Ti-Brite cleaned per AD 2-15.

6.2.1 Oxidation Control

Airtek is a licensee of the Temco-Pennsalt Chemical Company patented electrolytic Ti-Brite process, which process is performed on each pressure vessel. Approximately 0.2 - .5 mil of stock is removed after aging the pressure vessel to remove any possible interstitial rich embrittled outer layer from the vessel wall. The vessels with opening to the interior surfaces of less than approximately .500 diameter are too small for the Ti-Brite anode-cathode probe. Consequently, the internal inert gas purge during aging precludes surface oxidation.

6.0 MANUFACTURING PROCEDURE (continued)

6.3 MACHINING

Each part is machined to the requirements of the final detail machine drawing. Subsequent to the final machine operation, each part is fluorescent dye penetrant inspected per MIL-I-6866. Machining is per Airtek Specification AD 9-1.

6.4 WELDING

6.4.1 Weld Development

Prior to any welding, sample weld rings were machined to the exact configuration of the production parts. During the welding of the sample rings the optimum ranges of all welding machine variables were established.

Airtek's inert gas welding chamber with weld positioners was designed specifically for refractory metal welding. Airtek's Welding Specification 5-11 was used. All titanium pressure vessel welding is performed in Airtek's Engineering Laboratory. The welding chamber and equipment, x-ray reading, and quality assurance are subject to engineering approval on each vessel.

Subsequent to the welding operation the weld was visually inspected, then radiographically inspected per MIL-STD-453 and fluorescent dye penetrant inspected per MIL-I-6866. Three coupons were removed from the final test ring, and tested and the weld microstructure was examined.

6.4.2 Production Welding

Production welding was accomplished in the exact manner as determined during weld development, with all welding in accordance with the requirements of the established weld schedule.

Each tank, after welding, was radiographic and fluorescent penetrant inspected and final machined. Final dimensional inspection was performed to the drawing requirements.

6.5 FINAL MACHINING

After final heat treating, the final machining operations to the polar bosses were performed per AD 9-1. By this method the tight dimensional and concentricity controls were accomplished.

6.6 SHOT PEENING

As a last operation prior to acceptance testing the tank was completely shot peened in accordance with AD 2-8. Peening has proven beneficial for reducing residual stresses and improving surface condition.

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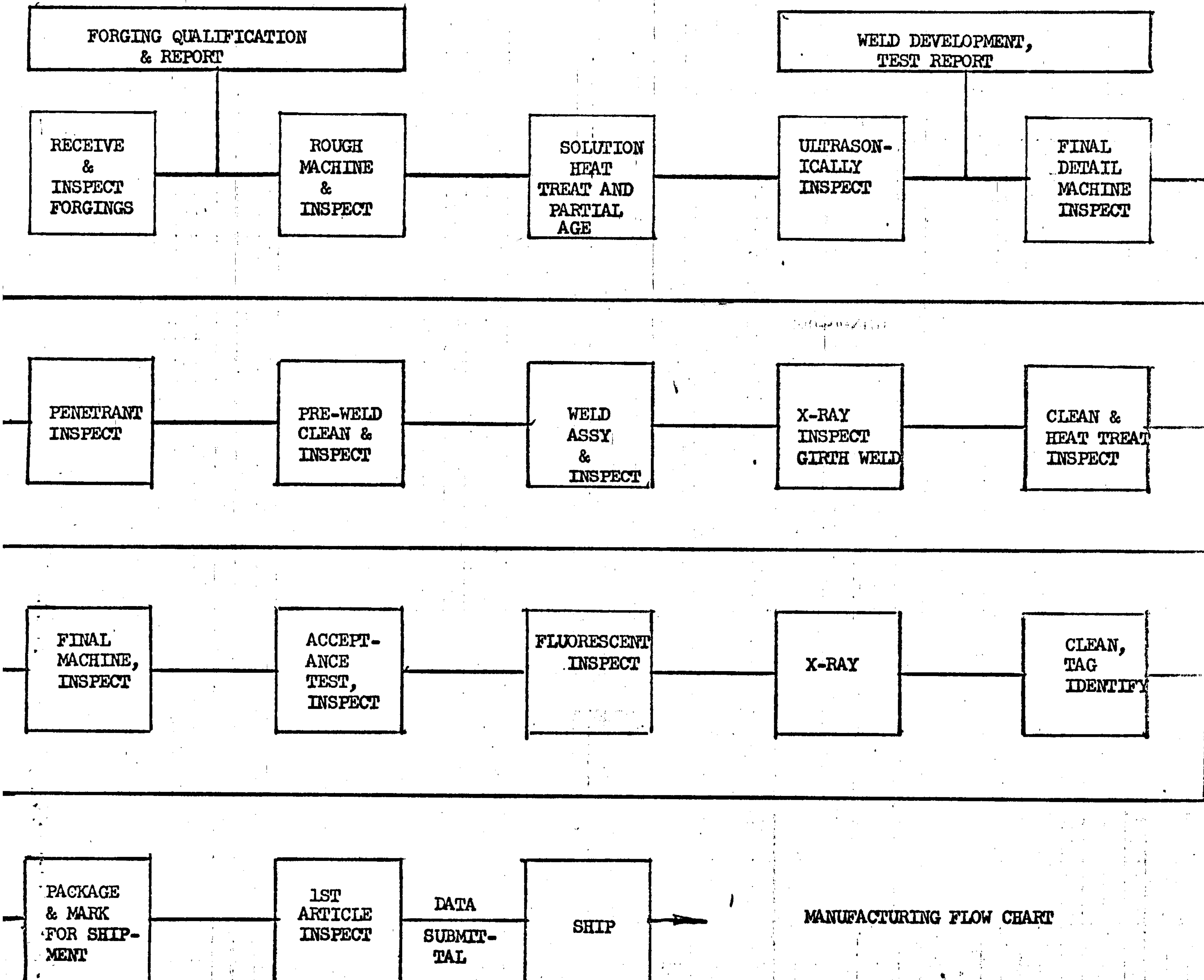
6.0 MANUFACTURING PROCEDURE (continued)

6.7 ACCEPTANCE TESTING AND CLEANING

Acceptance testing and cleaning were performed in the exact manner described in Airtek's Acceptance Inspection Plan Number AIP4425008.



MANUFACTURING FLOW CHART